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NEW PROGRESS OF RANGING TECHNOLOGY AT WUHAN SATELLITE LASER RANGING STATION

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ABSTRACT

A satellite laser ranging system with an accuracy of the level of centimeter has been developed. successfully at the Institute of Seismology, state Seismological Bureau with the cooperation of the Institute of Geodesy and Geophysics, Chinese Academy of Science. With significant improvements on the base of the second generation SLR system developed in 1985, ranging accuracy of the new system has been upgraded from 15cm to 3-4cm. Measuring range has also been expanded, so that the ETALON satellite with an orbit height of 20,000Km launched by the former U. S. S. R. can now be tracked.

Compared with the 2nd generation SLR system, the newly developed system has the following improvements:

(1) A Q modulated laser is replaced by a mode-locked YAG laser. The new device has a pulse width of 150ps and a repetition rate of 1-4pps.

(2) A quick response photomultiplier has been adopted as the receiver for echo, for example, the adoption of MCP tube has obviously reduced the jitter error of the transit time and therefore has improved the ranging accuracy.

(3) The whole system is controlled by an IBM PC/XT Computer to guide automatic tracking and measurement. It can carry out these functions for satellite orbit caculation, real-time tracking and adjusting, data acquisition and the preprocessed of observing data etc. , the automatization level and reliability of the observation have improved obviously.

INTRODUCTION

Satellite laser ranging(SLR) is a new measurement technology established with the advancement of laser, optoelectronics, computer, and space science. It has been widely applied in geoscience. Its observing date have already been used in many scientific fields such as geody-

namics, geodesy, astronomy and earthquake prediction.

It has especially shown its importance in monitoring the movements of global plates and reginal crust, determining geocentric coordinates, and studing of earth rotation parameters and gravitational field model. The 2nd generation SLR system finished in 1985 at the Institute of Seismology. The system has a measuring range of 8000Km and the accuracy of 15cm. In order to upgrade the equipment from 2nd to 3rd generation. So that the observing data of Wuhan SLR station can meet the need of monitoring crustal movements and the research of earth rotation parameters and solid earth itself, the Institute of Seismology and Institute of Geodesy and Geophysics established cooprative relation.

The 3rd generation system tracked satellite AJISAI of Japan and Lageos of US successfully several times in June 1988. After the preprocessed of observing data, the accuracy of single shot attained 5—7cm. Since August 1989, the quick-look data of the ranging results have been sent to GLTN of NASA. The accuracy of Lageos observing date of Wuhan SLR station back from GLTN is also about 5-6cm.

In April of 1990, F4129 micro-channel plate(MCP) is used to replace PM2233B photo multiplier and the accuracy reaches 3-4cm. At the same time ETALON-2 and ETALON-1 satellite with an orbit height of 20,000Km launched by the former U. S. S. R. in 1989 were also observed.

Measuring Principle of System and Performance of the Individual Parts

The ranging principle of the Wuhan SLR system is as follows: the ephmeris(provided by GLTN or CSR of Teaxs University) is input into an IBM PC computer before observation, in order to caculate and interpolate the satellite orbit. A real-time clock in the computer sends out a series of order signals to control the automatic tracking of the mount, to shoot laser beam, to pre-set range gate, to correct the pointing direction of telescope and range gate in real time and to collect observing data. At the moment of shooting laser the main pulse is sampled as the open signal for time interval counter. The echo from the retroreflectors of the satellite is received by a telescope with an aperture of 60cm. The optical signal is converted to an electronic pulse by MCP tube and then amplified to close the time interval counter and the time interval measurement is completed. Meanwhile, observing data is collected by the computer. , The whole measuring process is shown on the computer display. Observing object, caculating satellite position, or ways of interpolation and measurement can all be selected on the menu. Fig. 1 and Fig. 2 show the telescope and computer, control and electronic measurement system respectively. Table 1 is the performance of the main parts in the system.

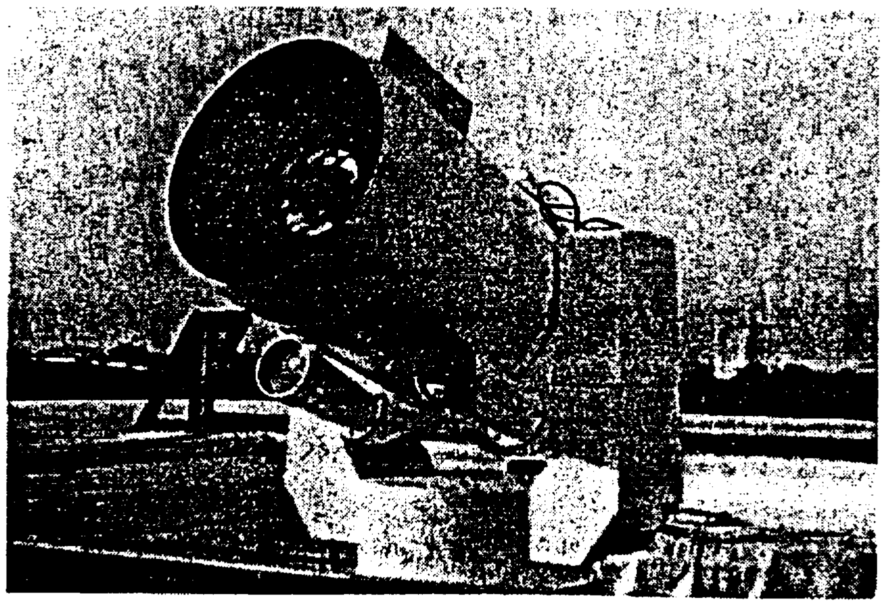


Fig. 1 The mount of Wuhan SLR system

Fig. 2 Receiving electronic equipment, computer and clock subsystem

Table 1 Specification of the satellite laser ranging system at Wuhan

Subsystem	Specification
Mount	
Configuration	elevation-azimuth
Tracking velocity	18 arcsec—0.5° per second
Synchronistic inductor	resolution 1 arcsec
Drive	DC torque motors
Orthogonality	±4 arcsec
Laser	
type	Nd:YAG
Wave length	0.532μm
Energy	50mj
Pulse width	150ps
Repetition	1-5pps
Receiving telescope	
Type	Cassegrain
Diameter	60cm
Field of view	1′-6′or 1°(use for sighting satellite)
Filter	1nm
Transmitting telescope	
Type	Galilean
Diameter	10cm
Beam divergence	0.6′-3′ can adjustable
Sighting telescope	
Diameter	15cm
Field of view	3°
Receiving electronics	
PMT	ITT F4129 MCP
Amplifier	H/P 8447 D
Discriminator	Canberra 1428A
UTC clock	
Type	Cesium H/P 5061A
Stability	1×10^{-12}
Accuracy	2μs
Time interval counter	
Type	5370B
Resolution	20ps
Micro computer	IBM PC/XT

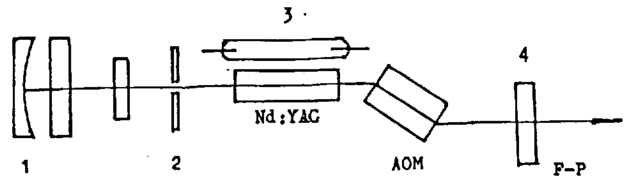
Main Improvements

1. Nd : YAG ultra-short pulse mode-locked laser is used

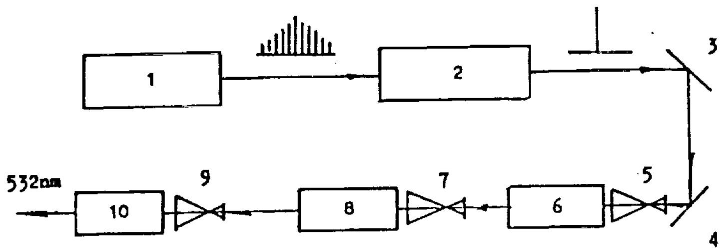
An active and passive mode— locked laser with Nd : YAG as laser material is used in the new SLR system. Fig. 3 is block diagram of laser. Infrared light output of 100 mJ in energy, 1. 06μm in wavelength, and 150ps in pulse width is got from laser with one stage oscilator and three stage optical amplifier. It is converted to green light of 50mJ in energy, 532nm in wave-length and 1-4pps adjustable in repetition rate. Compared with the Q modulated device(4. 5ns inpulse width, 0. 25J in energy) used in the 2nd generation system, The new laser improved the ranging accuracy, because the pulse width is reduced greatly Table 2 shows the comparision of ranging accuracy between adopting Q modulated device and mode-locked device, while other conditions are the same.

Table 2. The Comparision of ranging accuracy between Q modulated and mode—locked laser from LAGEOS

DATE	TIME	OBS	Wuhan RMS(cm)	GLTN RMS(cm)	LASER
1985. 08. 02	23:44	103	13. 9		YAG Modulated Q
8. 03	22:20	370	15. 8		
8. 14	21:26	131	14. 6		
8. 16	22:21	105	15. 4		
9. 11	22:01	280	14. 9		
9. 28	20:02	320	14. 7		
10. 05	21:03	101	16. 1		
10. 07	21:50	170	15. 7		
1989. 11. 27	18:50	471	5. 7	5. 1	YAG Mode-Locked
11. 28	17:34	431	5. 7	5. 1	
11. 28	21:07	303	5. 7	6. 5	
12. 01	17:04	144	6. 1	6. 5	
12. 01	20:28	483	6. 3	6. 5	
12. 02	19:04	176	7. 3	5. 1	
12. 03	17:44	330	7. 5	5. 3	
12. 03	21:18	438	6. 7		



High Repetition Rate Ultra-short Pulse Oscillator
1-Rear mirror contacted by dye cell with circulating system. 2-Transverse mode selecting aperture.
3-Xe flash lamp. 4-Front mirror.



1-Ultra-short pulse oscillator. 2-Single pulse selector. 3,4-45° mirrors. 5,7,9-Beam expanders. 6-First stage of amplifier. 8- Two stage of amplifier. 10-Harmonic generator.

Fig. 3 Schematic Diagram of Repetition Rate Ultra-short Pilse Laser System

2. Improvement of opto-electronic detector PM2233B photomultiplier is employed as detector for main and echo pulse in the 2nd generation SLR system, the transit time of electron in the whole tube is relatively long so the jitter error will become very important for precise ranging. In order to overcome this shortcoming, F4129 MCP photomultiplier with 1ns transit time is used for detecting echo in the 3rd generation system. The jitter error is sharply reduced because the distance between the cathode and micro-channel plate is just 0. 6μm . Table 3 shows the observing results before and after the photomultiplier is replaced. Data processing by GLTN, Delft University and ourselves, all show that the ranging accuracy has upgraded from 5-7cm to 3-4cm.

Table 3. the Observing results before and after the photomultiplier is replaced from LAGEOS

DATA	AOS	LOS	OBS	Wuhan RMS(cm)	GLTN RMS(cm)	DELT1 RMS(cm)	PMT
SAT. LAGEOS							
90. 3. 6	17:55:15	18:17:48	81	8. 1	5. 6	6. 4	PM 2233B
3. 7	16:24:58	16:51:52	210	7. 1		6. 4	
4. 4	13:32:14	14:11:08	308	8. 4		7. 2	
4. 12	13:11:49	13:50:55	47	8. 8	7. 8	8. 0	
4. 13	15:25:13	15:56:08	265	7. 5	4. 7	6. 1	
4. 19	14:16:44	14:57:38	675	6. 4	5. 4	6. 1	

4.25	13:04:01	13:44:19	312	4.5	4.4	4.9	F4129 MCP
4.26	11:48:11	12:19:58	346	6.3	6.1	4.9	
4.26	15:18:14	15:47:42	387	4.6	4.8	4.9	
5.4	11:49:50	12:00:50	40	4.1	3.7	3.5	
5.4	15:01:39	15:26:16	274	3.9	5.0	3.5	
5.5	13:36:30	14:11:07	643	3.8	3.2	3.3	
5.6	12:17:38	12:41:51	123	3.9	2.9	3.3	
5.9	11:50:05	12:06:31	252	4.0	3.4	3.3	
5.17	14:54:44	15:16:12	355	3.8	2.1	1.6	
5.18	13:26:49	14:05:00	1050	3.8	2.2	2.8	
5.19	12:07:34	12:37:50	530	3.8	2.2	2.0	
5.24	12:22:27	12:54:50	630	3.6	4.4	2.8	
5.25	14:37:25	14:55:54	163	4.1	2.3	2.0	
5.27	12:07:14	12:24:11	114	3.8	2.0	2.0	
6.1	12:02:29	12:35:54	491	3.8	1.3	1.8	
6.8	13:13:31	13:31:57	294	3.6		1.8	
6.10	13:54:12	14:16:18	164	4.3		1.8	

3. Automatization and reliability greatly improved with the use of IBM personal computer.

Though the 2nd generation system at Wuhan SLR station has realized automatic track for the first time in China. "Automatic" only means the numerical guiding of the mount since only two 8-bit single board micro-computer is used for real-time control while orbit elements of the satellite (one set for every 20 second) is caculated by VAX-750 computer and is input from Keyboard manully. Heavy work loud, low information convey speed, frequent handling error are among the shortcoming. the 3rd generation SLR system adopts IBM PC as its control center. Real-time clock range, gate controller, data acquisition and laser shooting controller, etc. which are originally in the instrument cabinet are extended in programmable functions and are reduced in volume, so that they combined on two extending boards to be installed in the extension slot of IBM PC computer. With these change, the structure is compacted and reliability raised. Software regarding ephemeris, data processing, numerical track guiding, software managing, etc. are all transplanted to IBM PC computer. While working, the telescope is automatically guided towards the satellite by the track control part with the caculating result from ephemeris. In order to improve tracking accuracy, tracking parameters(time, azimuth, elevation) can be displayed and corrected in real time during the observation. Observing results and o-c difference are also displayed in both digital and graphical ways, so that the operator can understand working state and correct parameter to improve hit rate. Once observation end, the preprocessing is selected to analyze ranging data. By the manner of the menu

the operational course are simplified greatly. These improvements decreased the misoperation and raised the efficiency. Fig. 4 shows the display of some parameters on computer screen during the operation.

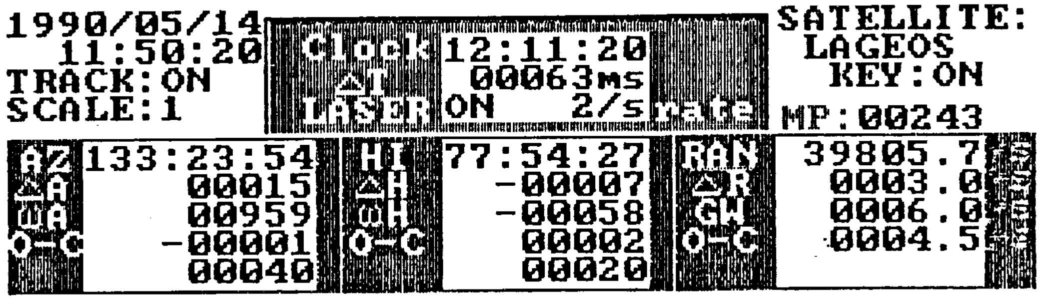


Fig. 4 The display of some parameters on computer screen during the operation

In addition, other improvement are also carried out e. g. 5370 B time interval counter is instead of old one and stability of laser output and the accuracy of mount pointing are also improved. We are also striving to realize daytime observation and to improve other performance of system to better the use of SLR technology for geoscience research.

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Mobile System

Upgrades/Developments